Life Cycle Analysis of the R-Power Tallow Biodiesel Fuel Pathway

Introduction:

Site Location and Capacity

The R Power plant is sited at the Port of Redwood City, California on property leased by Seaport Refining and Environmental. While there are significant logistical advantages of locating at the Seaport transmix facility (use of existing tankage, loading, wastewater treatment, and other facilities), an environmental advantage is the availability of waste heat generated by Seaport's processing of transmix, which reduces R Power production and energy costs and the environmental footprint of the R Power biodiesel production process. (R Power obtains approximately half of the BTUs needed from waste heat). R Power obtains the remainder of its energy requirements in the form of electricity from the grid. R Power's current production plant can produce, on average, 2,000 gallons per day of biodiesel. Plans are underway to expand the existing plant to 42,000 gals/day (additional notice will be provided to CARB upon expansion).

The Seaport Refining transmix operation generates significant quantities of waste heat as it distills waste mixtures of petroleum products from various oil refineries and terminals in the Bay Area into gasoline, diesel and other fractionated components for recycling into the regional fuel market. The transmix process distills these products at several hundred degrees Fahrenheit, and prior to the R Power plant co-locating there, waste heat was not recovered and was vented and radiated to the atmosphere.

To recover the waste heat, R Power installed several heat exchangers whereby pre-heated diesel from the transmix operation is used to provide heat to the R Power system. This has also resulted in a very efficient way of cooling the Seaport diesel product (which must be cooled for sale and is currently cooled with an air "fin fan" cooling system which draws electricity from the grid for power). The R Power heat exchange system has resulted in a reduction in the use of the Seaport cooling system, an additional efficiency of the system.

Process Overview

R Power Biofuels uses a standard FAME transesterification process. R Power's biorefinery is a continuous-flow system; it is a water free, closed-loop process, which does not produce any emissions other than those related to storage of methanol in vapor-controlled permitted tanks. In addition, there is no combustion equipment used on-site for the process.

Feedstock Rendering, Acquisition, and Storage

R Power currently uses high-energy rendered tallow for its feedstock; roughly one gallon of rendered tallow produces one gallon of biodiesel at current throughputs and yields. Storage tanks for feedstock and finished fuel are sited in a Containment Enclosure. We currently purchase feedstock tallow from **Confidential Information has been redacted** (other similar suppliers are also available) in loads of 50,000 pounds. The feedstock storage tank has a hot oil coil using recovered heat to maintain the feedstock in a liquid state suitable for pumping. R Power assumes (based on CARB's Tallow to Renewable Diesel Pathway) that there is no commercially viable alternative use for animal waste. As such, transport of animal waste to a disposal site is the alternate fate.[1]

Process Units

Specific process units include:

- feedstock pre-treatment to remove excess water and impurities,
- chemical addition (methanol and catalyst),
- mixing and reaction of the raw materials,
- methanol recovery through a methanol stripper (recovered methanol is then returned to the methanol storage tank for reuse in the process),
- glycerin removal and recovery,

[1] California Air Resources Board.(2009). Detailed California-Modified GREET Pathway for Co-Processed Renewable Diesel Produced from Tallow (U. S. Sourced).Retrieved 08-24-2011. http://www.arb.ca.gov/fuels/lcfs/092309lcfs_tallow_rd.pdf

- **confidential business information has been redacted**
- addition of stabilizer and red-dye (for off-road use). This is accomplished at the loading rack prior to sale.

Scenario: R Power has a production facility in Redwood City, California and is applying for a Method 2B pathway to generate biodiesel fuels from mixed tallow. However, rather than complete an analysis for their own facility, R Power opted to use the California Air Resources Board's (ARB) Tallow Renewable Diesel (RD) and Soy Biodiesel (BD) pathway calculations. The combination of these two pathways will be a hybrid pathway for the R Power facility. This hybrid model is a single, self-contained CA-GREET model constructed from the tallow renewable diesel pathway and the soy biodiesel pathway. The actual carbon intensity (CI) for this facility will be lower for each step of the process than the two ARB pathways.

Energy Requirement

Energy usage in the R Power production facility is lower than otherwise anticipated due to the significant amount of waste heat (recovered from co-located transmix production processes) used to produce R Power biodiesel. The single off-site energy used in the process is electricity provided by PG&E for motors powering pumps, **Confidential Business Information has been redacted,** and the hot oil heater. The sum of the various motors is approximately 100 HP. For an operating day, this equates to approximately 1.8 MWH. **Confidential business information has been redacted.**

Additionally, feedstock is sourced locally, as the tallow feedstock is generated in California. Waste animal carcasses are transported by heavy duty diesel trucks (HDDT) from the meat packing plant to a rendering plant in California. Rendered tallow is then shipped via HDDT on average approximately 50 miles to R Power's Redwood City storage and production facility. R Power assumes (based on CARB's Tallow to Renewable Diesel Pathway) that there is no commercially viable alternative use for

animal waste.[2] As such, transport of animal waste to a disposal site is the alternate fate.

Assumptions from the ARB Pathways:

From the ARB pathway, the rendering process uses 6,026 Btu/lb of tallow[3]. ARB allocates emissions between the BD and the glycerin co-product on an energy basis. Since BD contains 95.1 percent of the total product energy and glycerin contains 4.9 percent, emissions are allocated on this percentage basis. The 4.9 percent is a standard fraction of energy allocated for glycerin co-products from BD production thus, of the total process emissions, 95 percent are allocated to the BD. The total transesterification energy to convert tallow to glycerin is 2,116 Btu/lb of BD[4] produced. **Confidential Business Information has been redacted.** For the final step in this scenario, 80 percent of the total BD produced is transported 50 miles by HDDT to blending stations. Once blended, the fuel is transported 90 miles by HDDT to refueling stations. The other 20 percent is transported directly to nearby refueling stations.

These are conservative estimates as R Power currently blends biodiesel to specification grade on-site, and ships blended product to customers. Current R Power customers are within 90 miles of the R Power Redwood City plant.

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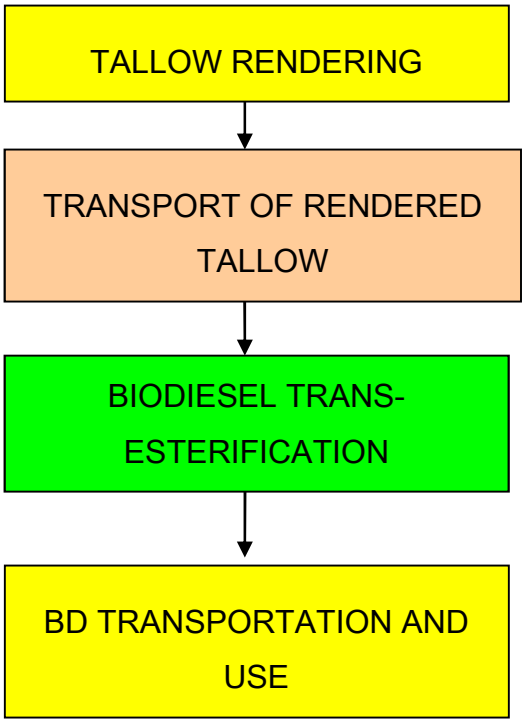
[2] California Air Resources Board.(2009). Detailed California-Modified GREET Pathway for Co-Processed Renewable Diesel Produced from Tallow (U. S. Sourced).Retrieved 08-24-2011. http://www.arb.ca.gov/fuels/lcfs/092309lcfs_tallow_rd.pdf

[3] California Air Resources Board.(2009).Detailed California-Modified GREET Pathway for Conversion of Midwest Soybeans to Biodiesel (Fatty Acid Methyl Esters-FAME). Retrieved 08-24-2011. http://www.arb.ca.gov/fuels/lcfs/121409lcfs_soybd.pdf

[4] California Air Resources Board.(2009). Detailed California-Modified GREET Pathway for Co-Processed Renewable Diesel Produced from Tallow (U. S. Sourced).Retrieved 08-24-2011. http://www.arb.ca.gov/fuels/lcfs/092309lcfs_tallow_rd.pdf

Figure 1: Process Flow Diagram of Tallow Renderings to Biodiesel



The whole lifecycle pathway takes into the above glycerin co-product percentage, and a loss factor of 1.000038 as specified in referenced biodiesel lifecycle reports by ARB (ARB, 2009)[5].

[5] California Air Resources Board.(2009).Detailed California-Modified GREET Pathway for Conversion of Midwest Soybeans to Biodiesel (Fatty Acid Methyl Esters-FAME). Retrieved 08-24-2011. http://www.arb.ca.gov/fuels/lcfs/121409lcfs_soybd.pdf

Summary:

Based on the above assumptions, CA-GREET calculates the GHG emissions shown in Table 1.

Table 1: Summary of Carbon Intensity Associated with Biodiesel Production from Tallow by GHG Components

GHG Components	Tallow Production (Rendering and transport), g/MMBtu	Biodiesel Production (Trans-esterification, transport and distribution), g/MMBtu	Total Well to Tank, g/MMBtu	Total Well to Tank, gCO2e/ MJ	Total Tank to Wheels gCO2e/ MJ	Total,
VOC	3.40	2.11	5.51	0.02		0.02
CO	13.45	5.13	18.58	0.03		0.03
CH4	49.04	18.12	67.16	1.59	0.045	1.635
N2O	0.24	0.06	0.29	0.08	0.735	0.815
CO2	2,971.22	5,473.52	29,444.74	27.91	3.7	31.61
Total, gCO2e/MJ	**23.98**	**5.65**	**29.63**	**29.63**	**4.48**	**34.11**

Table 2 breaks out the CI by process, as calculated by CA-GREET, for biodiesel production from tallow.

Table 2: Summary of Carbon Intensity Associated with Biodiesel Production from Tallow by Process

Components	Carbon Intensity, g/MJ
Tallow Rendering	23.5
Tallow Transportation and Distribution (T&D)	0.48
Biodiesel Trans-esterification	4.89
Biodiesel T&D	0.76
Total Well to Tank	**29.63**
Total Tank to Wheels	**4.48**
Total Well to Wheels	**34.11**

Table 3 shows the specifications and factors of tallow, biodiesel, and glycerin used in the calculation of the ARB's Tallow to Renewable diesel pathway.

Table 3: Specifications used in the Tallow to Biodiesel Calculations

BD Lower Heating Value (Btu/lb BD)	Tallow to BD ratio (lbs Tallow / lb BD)	Glycerin energy allocation	Loss Factor
16,149	1.04	4.9%	1.000038

Table 4 shows the total energy input for each process of the tallow to renewable diesel pathway calculation.

Table 4: Energy Input for Each Process

	Thermal Energy	Electricity	Total
Rendering Energy (Btu/lb tallow)	5,354.70	671.30	6,026
Biodiesel Trans-esterification (Btu/lb or gallon BD)	2,069	47	2,116

Conclusion:

The above life cycle analysis report is based on the survey data from reports referenced in this document.

Sample Calculations:

This section presents a sample calculation for CO_2 emission from tallow processing found in Table 1 of this document.

CO_2 Emissions per Energy Input = (Rendering Emissions + Transportation Emissions) X (Tallow to Biodiesel Factor/Biodiesel Lower Heating Value) X 1,000,000 BTU/MMBTU X Glycerin Adjustment Factor

Where: Rendering Emissions = 383.55 gCO_2/lb Tallow Rendered

Transportation Emissions = 7.97 gCO_2/lb Tallow Transported

Tallow to Biodiesel Factor = 1.04 lb. Tallow/lb Biodiesel

Biodiesel Lower Heating Value = 16,148.68 BTU/lb Biodiesel

Glycerin Adjustment Factor = 95.07 Percent

(383.55 + 7.97) gCO_2/lb. X (Tallow x 1.04 lb Tallow/lb. Biodiesel ***/*** 16,148.68 BTU/lb Biodiesel) X 10^6 BTU/MMBTU X 0.9507 = 23,971.42 gCO_2/MMBTU

Attachment A – Fuel Inventory

As R Power is just beginning production, there is no historical data from 2009 or 2010 to summarize.

Attachment B

List of Combustion Equipment as permitted in the District Air Permit

The project has no combustion equipment.

Attachment C

Applicable Permits

The project has all approvals needed to operate including those acquired through co-location at the Seaport Refining and Environmental site. The R Power process has no emissions other than potential VOC emissions from the methanol tank, and R Power obtained a methanol storage tank permit (below) from the BAAQMD.

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SINCE 1955

October 1, 2010

Seaport Refining and Environmental LLC
679 Seaport Boulevard
Redwood City, CA 94063

Attention: Joaquin Camara

Application Number: 21932
Plant Number: 15136
Equipment Location:
700 Seaport Boulevard
Redwood City, CA 94063

Dear Applicant:

SUBJECT: CHANGE OF PERMIT CONDITIONS

This letter is to advise you that your application for changes in permit conditions for the following equipment has been approved:

S-62 Tank 205
S-63 Tank 207

Operation of this equipment will be subject to permit condition no. 23747 which is attached. If you have any questions regarding this matter, please call **Madhav Patil, Air Quality Engineer II at (415) 749-4674.**

Very truly yours

Jack P. Broadbent
Executive Officer/APCO

by _____
Engineering Division

Attachment D - Engineering Process Diagram

Confidential Business Information has been redacted.

Attachment E - CA-GREET Input Values Modified (cells location, values modified)

We only used the ARB's default values in our GREET analysis. No default values were changed.